THE DESIGN AND BUILD OF A GAS BEARING GYROSCOPE POSSESSING HIGH G AND STERILIZATION CAPABILITY AND UTILIZING A LOW POWER GAS BEARING SPINMOTOR AND HIGH FREQUENCY PUMP

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Prepared by: J. M. Bremer
Senior Development Engineer

Approved by: S. J. Korzenowski
Project Engineer

R. G. Baldwin
Section Head

T. W. Garvey
Program Administrator

Honeywell Inc.
Aerospace Division
Minneapolis, Minnesota

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ABSTRACT

The sixth quarter work on the design, build, and test of a gas bearing gyroscope possessing high g and sterilization capability and utilizing a low-power gas bearing spinmotor and high-frequency pump has produced a preliminary gyro assembly and initial gyro test results.

Steps have been taken to correct several problems noted in the initial testing and a partial assembly of the final device has been produced. Future work includes the final assembly and testing of the gyroscope.

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SECTION I
SUMMARY

The purpose of this contract is to build a gyroscope possessing high g and sterilization capability utilizing a low-power gas bearing spinmotor and high-frequency pump.

PROGRESS (SIXTH QUARTER)

- Completion of functional tests on the preliminary build unit
- Build of redesigned stator incorporating windings change and metal encasement
- Build of spinmotor incorporating new stator
- Final assembly, incorporating additional magnetic shielding
- Completion of new header assembly with increased bellows capacity
- Completion of contamination investigation

PROBLEMS (SIXTH QUARTER)

- Several development problems were uncovered with the first build (bellows capacity, spinmotor reaction torque, and marginal spinmotor torque). Design changes were implemented to correct these deficiencies.

FUTURE WORK (SEVENTH QUARTER)

- Completion of final gyro build
- Start of gyro test program

SECTION II
DISCUSSION

PRELIMINARY BUILD TEST RESULTS

Although testing at the gimbal level had indicated some variability in starting voltage, it was decided to proceed with gyro build to determine whether any problems would result from integration of the piezo pump to the gyro.

The resultant gyro performed well, exhibiting very low drift rates, fast response time, and good repeatability. Runup-to-runup stability was unacceptably high, indicating a magnetic interaction between the spinmotor magnetics and the torquer magnets. The unit was subjected to the required vibration, shock, and acceleration environments and continued to perform well after each.

The bellows position was such that sufficient travel was not available to reach sterilization temperatures. A hole was tapped in the gyro header and a small quantity of flotation fluid allowed to bleed before the hole was re-sealed. This adjusted the bellows position, but unfortunately some small amount of air was also introduced into the fluid and caused pump malfunction after the first sterilization exposure. The loss of the pump precluded measurement of gyro performance parameters, such as transfer function, drift parameters, or stops after sterilization. However, visual examination, impedance measurements, and spinmotor testing revealed no damage had been done to the gyro as the result of the sterilization exposure.

STATOR CANNING

As previously stated in 20660-QR5, the variability in starting voltage on the stator used in the preliminary gyro build was attributed to either organic vapor or particulate contamination. A detailed visual examination of the gas bearing surfaces after the unit had been disassembled disclosed that a deposit had accumulated to form an annular ring on the thrust plate near the intersection of the thrust and journal bearings. Similar, though smaller, deposits were noted on the rotor in the same region. A 425X magnification of this ring is presented in Figure 1.

The infrared analysis shown in Figure 2 identified the material composing this ring as MS6293N, a filled epoxy used to impregnate the stator and MS7381A Bond master which is used to bond the stator laminations. Small particles of these materials evidently came loose from the stator and were drawn to the motor and deposited there by gas flow.

A new stator has been incorporated into the final unit, utilizing metal cans which completely enclose the exposed epoxy. The encased stator is shown in Figure 3. This will serve to prevent the loose epoxy particles discussed above and to prevent a reoccurence of variability in starting voltage.

The addition of the slot bridge necessitated a minor turns change in the stator. This change restores the original flux density in the gap to maintain sync margin, start margin, and power consumption. At the gimbal level after sterilization, starting voltages in all orientations on this motor were below 22 volts, and running power was 3.6 watts.

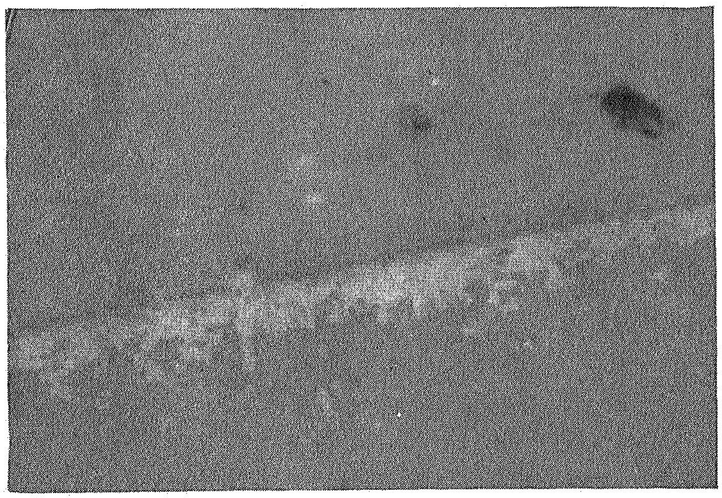

Figure 1. GG159E Contamination

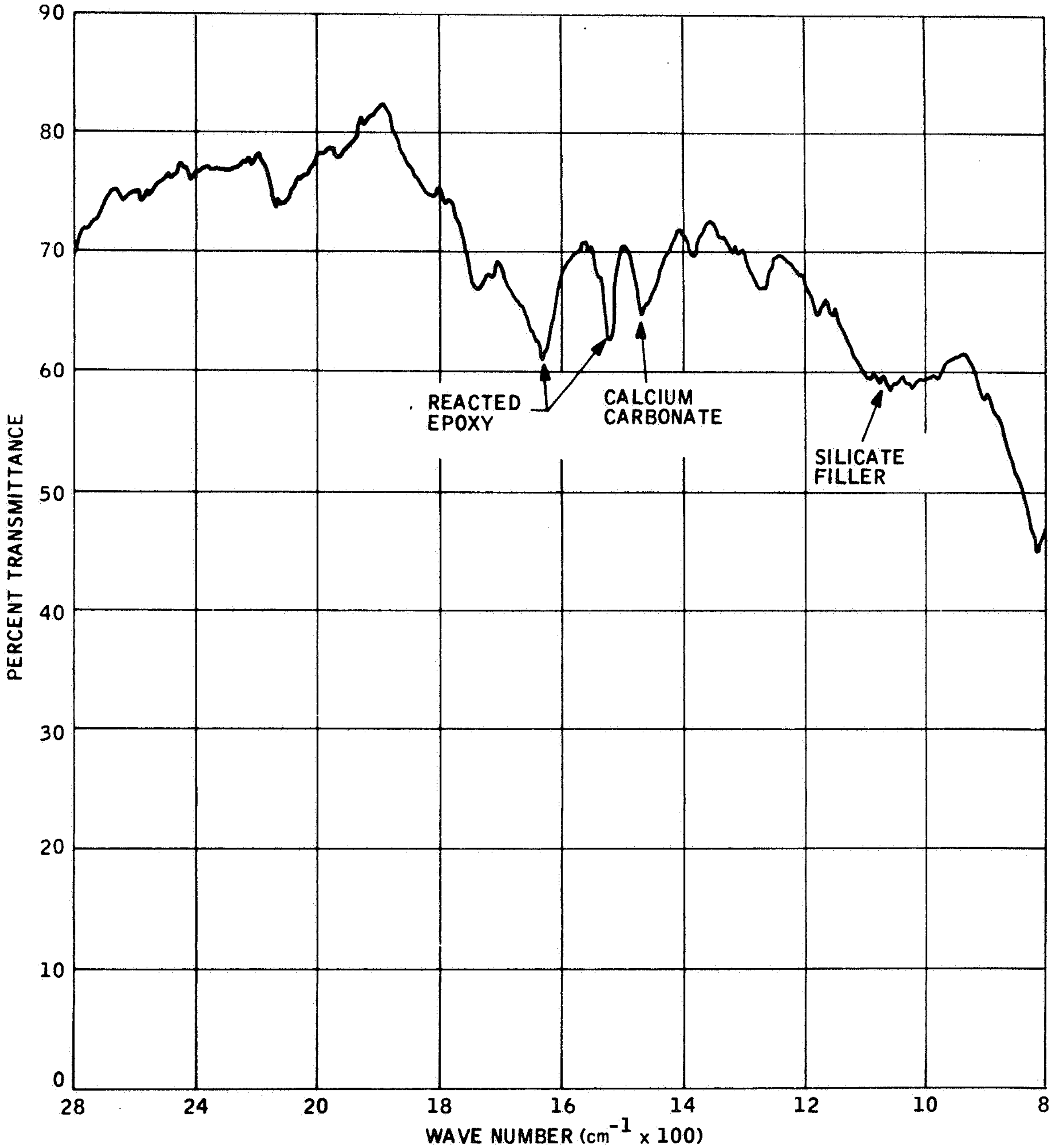

Figure 2. Infrared Spectrum of GG159E Contamination

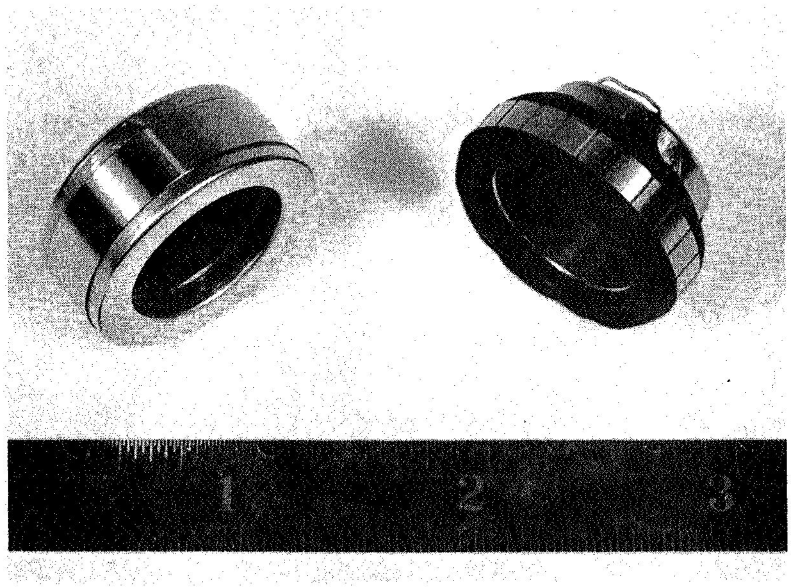

Figure 3. Encased and Standard Motor Stator

GIMBAL SHIELD

A mu-metal shield has been incorporated into the gimbal at the snout end to reduce the interaction between the motor and torque generator magnetics. This shield will servo to improve the runup-to-runup stability which had proved to be unacceptable in the test results on the preliminary gyro build.

The 800-cycle flux density, at the outside surface of the gimbal in the plane of the spin axis, was measured for three different stator configurations:

1) A stator without end cans
2) A stator with inconel end cans
3) A stator with mu-metal end cans

The result of these measurements is shown in Figure 4. Note that the greatest flux density occurs in the plane of the rotor hysteresis ring due to leakage through the ring. Since the H-ring is a permanent magnet material, its permeability is low. Note also that the mu-metal end cans reduce the end turn flux but do not affect the flux leakage through the H-ring.

Flux density measurements were made on the torquer end of the gimbal as shown in Figure 5. Three configurations were also mapped.

1) Without either the external or internal shield
2) With the regular external shield in place
3) With both the external shield and the 0.005-inch-thick internal shield

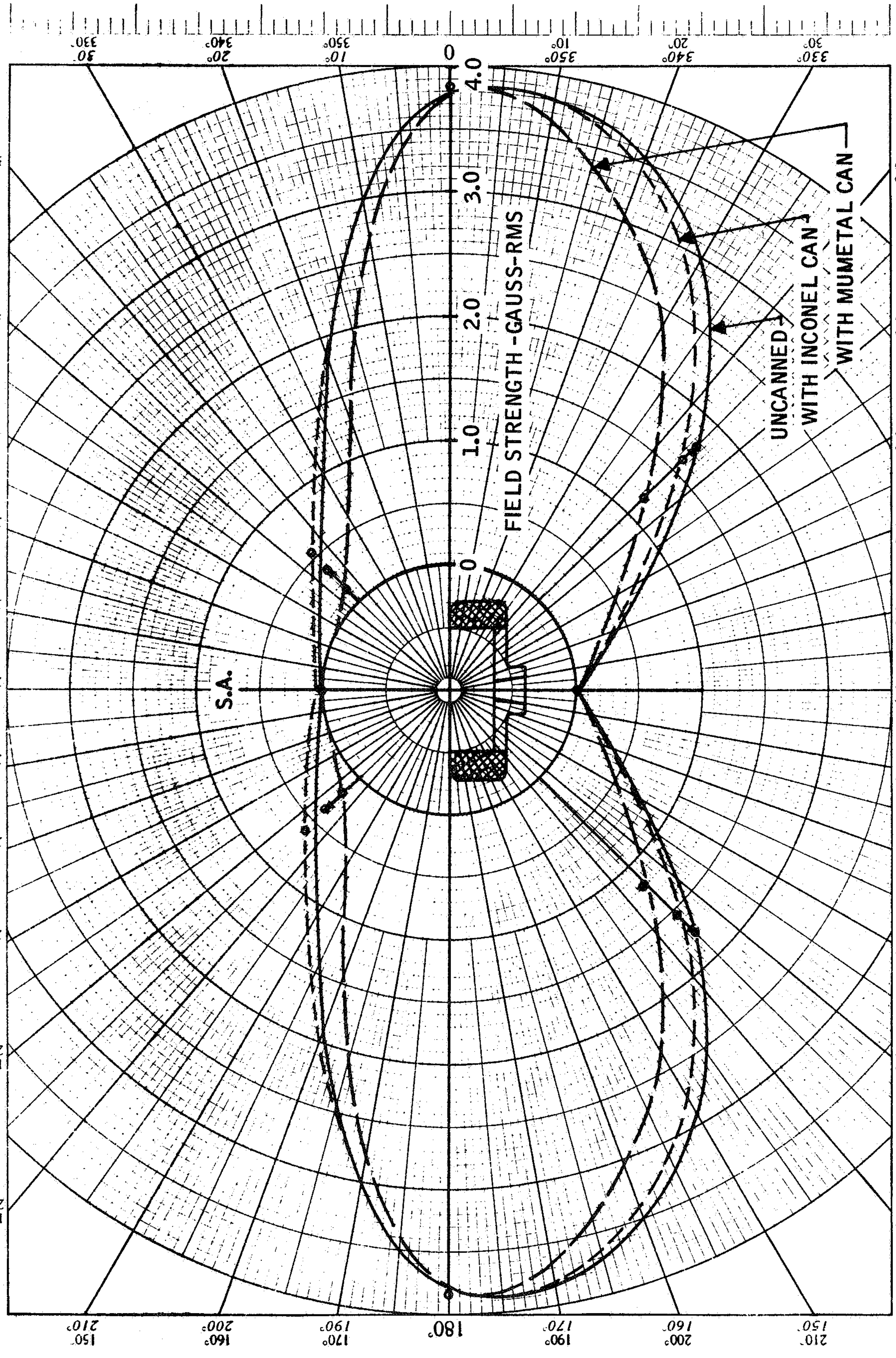

Figure 4. Field Strength Around Gimbal

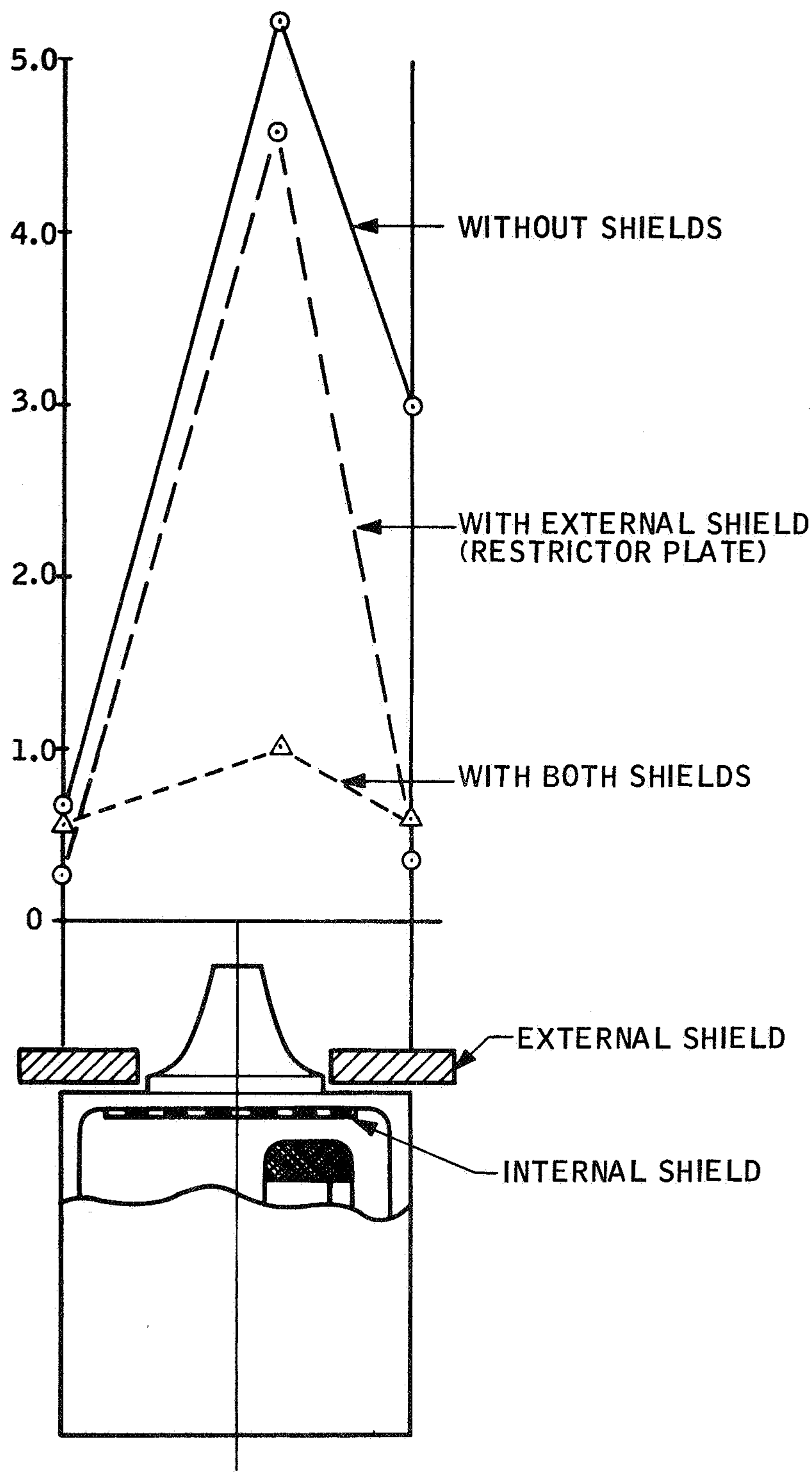

Figure 5. Field Strength in Gyro Spin Axis-Output Axis Plane

Since the external shield has a large center hole to clear the gimbal snout, it is not effective in shielding the flux leakage from the spinmotor. The internal shield attenuated the leakage flux by a factor of 5.5.

The nonsymmetry apparent in both Figures 4 and 5 is due to the stator being slightly off center with respect to the center line of the gimbal.

NEW HEADER DESIGN

Test results on the preliminary gyro build showed that additional bellows travel was necessary to withstand the temperature ranges demanded of this gyro. The test results are shown in Figure 6. The bellows was redesigned with additional displacement capability and has been incorporated in the final gyro assembly.

CONTAMINATION INVESTIGATION

The investigation to determine the sources of contamination which contribute to spinmotor lockup has been completed, the sources identified, and appropriate design changes made. Specific identification of the contamination in the GG159E preliminary build and the resultant design change, canning of the stator, have been discussed above. Other results are as follows:

- The lockup of specific gas bearing motors was due to organic particulate contamination and not vapor-condensed materials.
- The contamination is associated with bonding and encapsulating materials in the motor stator.

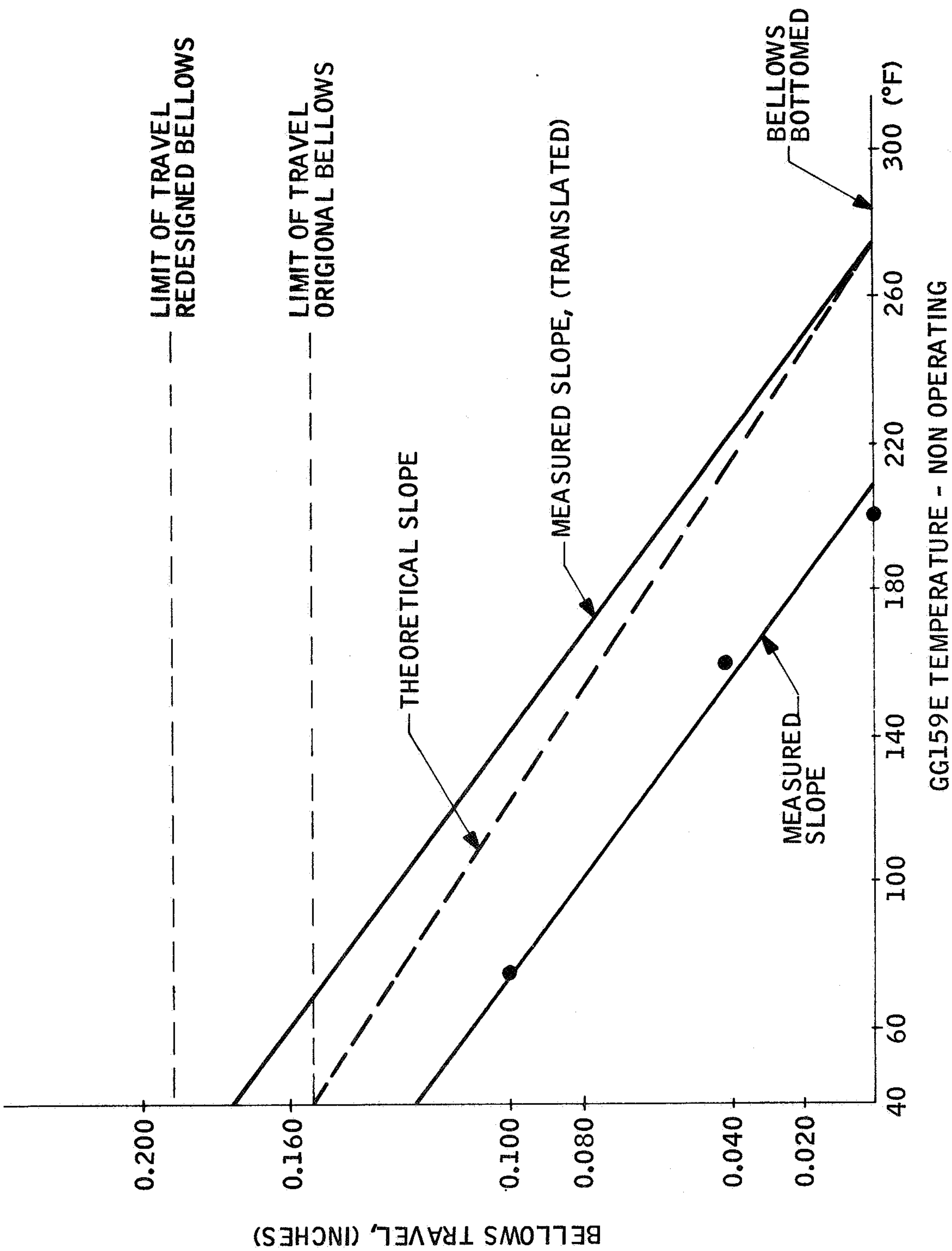

Figure 6. Bellows Travel versus Gyro Temperature

- Gas analysis of a sample filled gimbal showed the gas fill procedure used on the product line to be satisfactory.

- Materials presently used in spinmotor fabrication compare favorably with alternate materials tested either as used or with some additional processing. No material changes are anticipated.

- Water vapor and organic outgassing tests verified the original assumption that these phenomena would be much more prevalant at sterilization temperature. As a result, special vacuum-bake processes have been initiated.

SECTION III
SUMMARY

The final gyro build will be accomplished by 8 July 1968. The gyro will be tested and shipped in September 1968.